CALIFORNIA
ENERGY
COMMISSION

CALIFORNIA OUTDOOR LIGHTING STANDARDS (Revised March 2004)

STAFF REPORT

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Acknowledgements

Much of the information contained in this report is from the earlier report titled, "**Measure Identification Report, California Outdoor Lighting Standards,**" March 18, 2002. That report was prepared by California Energy Commission contractor, Eley Associates, along with subcontractors Benya Lighting Design, Heschong Mahone Group, Clanton & Associates, Inc., and RLW Analytics.

This new report has been written because many of the details that were contained in the earlier report needed revisions because significant modifications have been made to the proposed outdoor lighting standards since the earlier report was published.

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Overview

Energy Savings

The proposed outdoor lighting energy standards are justified on the basis of their energy savings. They conserve energy, reduce winter peak electric demand, and are technically feasible and cost effective. They set minimum control requirements, maximum allowable power levels, minimum efficacy requirements, and require cutoff luminaries to save energy by reducing glare. The recommendations for allowed lighting power are based on current Illuminating Engineering Society of North America (IESNA) recommendations for the quantity and design parameters of illumination, current industry practices, and efficient sources and equipment that are readily available. A 2002 baseline survey[1] of current outdoor lighting practice in California suggests that the majority of establishments currently are illuminated at substantially lower levels than IESNA recommendations.

Scope

Prior to these standards, the California Building Energy Efficiency Standards only applied to buildings that are conditioned; that is heated or cooled. In response to legislative requirement, the Standards have been modified to include lighting in unconditioned buildings and lighting for particular outdoor function areas.
These Standards have been developed for the lighting of:

- Unconditioned Buildings
- Hardscape for automotive vehicular use, including parking lots, driveways and site roads
- Hardscape for pedestrian use, including plazas, sidewalks, walkways and bikeways
- Building entrances and facades
- Canopies for vehicle service stations, other sales canopies, and non-sales canopies
- Outdoor sales lots
- Ornamental lighting
- Signs

These Standards do not apply to:

- Temporary outdoor lighting
- Lighting required and regulated by the Federal Aviation Administration, and the Coast Guard
- Lighting for public streets, roadways, highways, and traffic signage lighting, including lighting for driveway entrances occurring in the public right-of-way
- Lighting for sports and athletic fields
- Lighting for industrial sites, including but not limited to, rail yards, shipyards and docks, chemical and petroleum processing plants, and aviation facilities
- Automated Teller Machine lighting
- Lighting of public monuments
- Lighting used in or around swimming pools, water features, or other locations subject to Article 680 of the California Electrical Code
- Lighting of tunnels, bridges, stairs, and ramps
- Landscape lighting
- Decorative gas lighting
- Lighting for theatrical purposes, including performance, stage, and film and video production
- Lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation
- Emergency lighting powered by an emergency source as defined by the California electrical code

Alterations

Alterations of existing outdoor lighting systems will be subject to requirements similar to those currently in the Standards for alterations of existing indoor lighting systems. Alterations to existing outdoor lighting systems that increase the connected load or replace more than 50 percent of the existing luminaires will be required to meet the requirements for newly installed equipment. New signs that are installed in conjunction with alterations to existing buildings and with alterations to existing outdoor lighting systems, and alterations to existing signs that increase the lighting load or replace more than 50 percent of the existing ballasts will be required to meet the requirements for newly installed equipment. There will be no other requirements for existing lighting systems.

Environmental Impact

No negative environmental impact is associated with the proposed outdoor lighting standards. All of the impacts are positive. In addition to saving energy, some of the newer lighting technologies, which are encouraged by the proposed standards, last longer resulting in less need for disposal and/or recycling. The standards will not increase light pollution or light trespass. Finally, power plant pollutant emissions will be reduced from reduced electricity consumption.

Effective Date

These Standards will be adopted as updates to Title 24, Part 6, and will go into effect in conjunction with the upcoming triennial updates of the other parts of Title 24. Those updates are currently scheduled for effective dates in late 2005 or 2006. Between the time of the Commission's adoption of the Standards and their effective date, the Commission anticipates that the California utilities will focus Public Goods Charge funded programs on providing a transition process for early, voluntary compliance with the new Standards.

Compliance and Enforcement

These standards will be enforced through the plan checking and field inspection process already employed in Title 24. No new analysis tools are needed for compliance or enforcement, although the Commission intends to develop explanatory materials and forms as part of the Nonresidential Design Manual to aid the industry in complying with and building departments in enforcement of the new Standards.

Lighting Zones

A fundamental concept of the outdoor lighting standards is that allowable power levels are dependent on ambient illuminations levels that vary by lighting zones. Four zones are established, Lighting Zone (LZ) 1, LZ2, LZ3, and LZ4 based on the ambient illumination level zones recommended by both the Commission Internationale de l'Eclairage[2] (CIE) and the Illuminating Engineering Society of North America (IESNA).[3] Lighting zones serve a similar function as the climate zones, defined in the Title 24 Building Energy Efficiency Standards that determine requirements for energy budgets and measures required for compliance, such as insulation and fenestration performance characteristics.

The amount of outdoor lighting required at night for any given lighting application is partly a function of its surrounding ambient lighting conditions. The human eye is highly adaptable to different levels of light, but requires time, from seconds to minutes, to adjust to changes in illumination levels. In intrinsically dark environments, visual performance can be maintained at comparably lower levels of illumination, while in areas of high ambient illumination, higher levels of illumination are required for the same task. By matching allowable outdoor power levels to ambient illumination levels, visual needs can be met while also reducing the state's energy requirements.

The lighting zone approach correlates outdoor lighting power allotments to the ambient illumination levels of a local area. Overly high limits do not have to be set for all conditions, and likewise, overly restrictive regulations do not have to apply to areas with high ambient illumination levels. This optimizes the energy savings for each lighting zone.

The lighting zone approach allows for variation in standards by local preferences. Lighting zones are designated first by statewide defaults based on defined geographical areas. Local government jurisdictions have the authority to amend the zones for local conditions and purposes. The California Energy Commission will maintain a web-based list of local adjustments to the default lighting zones. Jurisdictions will amend the lighting zones through their normal public process for adopting local ordinances. They will be required to notify the Commission of the change in designation, with a detailed specification of the boundaries of the adopted Lighting Zones, consisting of the county name, the city name if any, the zip code(s) of the redesignated areas, and a description of the physical boundaries within each zip code; a description of the public process that was conducted in adopting the Lighting Zone changes; and an explanation of how the adopted Lighting Zone changes are consistent with the specifications in the Standards.

Summary of Proposed Standards

Minimum Lighting System Efficacy

For nonresidential and high-rise residential buildings and hotels/motels, the current 2001 Building Energy Efficiency Standards require that outdoor luminaries attached to or powered by the electrical service in buildings using lamps that are rated greater than 100 Watts have an efficacy of at least 60 lumens per watt, or be controlled by a motion sensor. The Standard has been modified so that the requirement will apply to all permanently installed outdoor luminaires.

These requirements do not apply to:

- Lighting required by a health or life safety statute, ordinance, or regulation, including but not limited to, emergency lighting
- Lighting used in or around swimming pools, water features, or other locations subject to Article 680 of the California Electrical Code
- Searchlights
- Theme lighting for use in theme parks
- Lighting for film or live performances
- Temporary outdoor lighting
- Light emitting diode, neon and cold cathode lighting

Availability, life cycle and cost are the same for the additional outdoor luminaries as those covered by the current Standards. Therefore, the broadening of the requirement is cost effective.

Controls

Automatic Controls

Automatic controls (either photosensors or astronomical time switches) are required by the current 2001 Standards to turn off outdoor lighting attached to or powered by the electrical service in buildings during the day and during other periods of time when it is not needed. This requirement has been expanded to include all permanently installed outdoor lighting, with the exception of lighting in parking garages, tunnels, and large covered areas that require illumination during daylight hours

The existing automatic control standard is cost effective. Availability, life cycle and cost are the same for this requirement as for the automatic control requirements for outdoor lighting under present standards. Therefore, the broadening of the requirement is cost effective.

Bi Level Controls

For lighting of building facades, parking lots, garages, sales and non-sales canopies, and all outdoor sales areas, controls will be required to provide the owner with the ability to turn off the lighting or to reduce the lighting power by at least 50% but not exceeding 80% when the lighting is not needed. Providing owners with the ability to partially turn off lighting when the lighting is not needed is consistent with the California Governor's Executive Order D-19-01, which required business to reduce outdoor lighting loads by 50% after business hours. It should be noted that there are no curfew requirements in the Standards.

Bi-level controls are not required for:

- Lighting required by a health or life safety statute, ordinance, or regulation, including but not limited to, emergency lighting.
- Lighting for steps or stairs that require illumination during daylight hours.
- Lighting that is controlled by a motion sensor and photoelectric switch.
- Lighting for facilities that have equal lighting requirements at all hours and are designed to operate continuously.
- Temporary outdoor lighting.
- Internally illuminated, externally illuminated, and unfiltered signs

Bi-level controls are cost effective. Using automatic time switch control devices and photocells is a standard method of controlling exterior lighting. In some cases, the requirement for bi-level control may require the use of a time switch with multiple channels of control. This is usually an incremental cost increase to the lighting controls already used for basic exterior on/off control. Typically about 50% of the exterior lighting can be reduced during roughly 50 - 60% of the non-daylight hours. This gives about a 25% energy savings over not having bi-level exterior lighting controls.

Table 1

Bi-level controls Net Present Value

Lot size	40,000 sf
Pole height	20 ft
Luminaire wattage	250 w, one per pole
Pole grid	70’ x 80’
Number of poles needed	10
Number of 277 volt circuits	1 or 2 depending on the switching
No additional raceways are needed	
Additional wiring needed	1,200 ft of new wiring, roughly 100 ft per pole (10 poles), plus 200 ft for the homerun
Cost of additional wiring per foot	10 cents per foot for #10 gage wire
Total costs of additional wire	1,200 ft x 0.10 /ft = $120
Cost of time controller (time clock)	$150 per circuit, only one needed for this example
Total additional project cost for time clock strategy	$120 (wires) + $150 (time clock) = $270
Total additional project costs for hi/lo strategy	$1,050 hi/lo equipment per circuit (only one needed here) + $120 (wires) = $1,170
Annual kWh savings	250 w per fixture x 5 fixtures (half of 10 fixtures) x 12 hrs/night x 365 nights/yr x 0.35 savings fraction / 1000 w/kW = 1,916 kWh
Assume equipment life is unaffected by this strategy	
Net present value of electricity for nonresidential projects with a time horizon of 15 years	$1.37 from 2005 Life Cycle Cost Methodology Report, Eley Associates
Savings net present value	1,916 kWh x $1.37 per kWh = $2,625

Shielding

Outdoor luminaires that use lamps rated greater than 175 watts in hardscape areas, building entrances, canopies, and outdoor sales areas will be required to be designated Cutoff for light distribution. The Standards do not require the use of full-cutoff luminaires. Cutoff is a luminaire light distribution classification where the candela per 1000 lamp lumens does not numerically exceed 25 at or above a vertical angle of ninety degrees above nadir, and 100 at or above a vertical angle of eighty degrees above nadir. Nadir is the point on the celestial sphere that is directly opposite on a vertical line from the zenith (highest point in the sky). Ninety degrees above nadir is horizontal. Eighty degrees above nadir is 10 degrees below horizontal.

Shielding is not required for:

- Internally illuminated, externally illuminated, and unfiltered signs
- Lighting for building facades, public monuments, statues, and vertical surfaces of bridges
- Lighting required by a health or life safety statute, ordinance, or regulation, including but not limited to, emergency lighting
- Temporary outdoor lighting
- Lighting used in or around swimming pools, water features, or other locations subject to Article 680 of the California Electrical Code

The requirement for cutoff luminaries saves energy by reducing glare. Glare may create a loss of contrast or an afterimage on the retina of the eye reducing overall visibility[4]. Cutoff lighting equipment will improve the effective distribution of light while allowing flexibility in utilizing products that address tradeoffs in energy, safety and security and operating costs[5]. "Glare reduces the contrast of the visual retinal image, thereby requiring a higher adaptation luminance to produce a compensating increase in contrast sensitivity. The glare source itself also increases adaptation luminance, but not enough to compensate for the decreased image contrast when the glare source is located close to the task. Glare sources on or near the line of sight produce after-images that decrease sensitivity as well. These after-images markedly reduce visual sensitivity"[6].

The luminaire cutoff requirement is cost effective. Most cutoff luminaires do not cost more than non-cutoff luminaires. Energy operating costs will be lower so the proposed measures will result in lighting designs that are cost effective.

Allowed Lighting Power Densities

The current standards do not have power limits for outdoor lighting. Adopting power requirements for specific outdoor lighting function areas is a key feature of these Standards. Allowed power is expressed as lighting power densities (LPDs), a concept well understood in the code enforcement and compliance community. The allowed lighting power is determined by measuring the area or length of the lighting application and multiplying this area or length times the LPD, which is expressed either in W/ft^2 or W/ft, respectively.

Using the concept of LPDs requires that the area of the lighting application be defined exclusive of any areas on the site that are not illuminated.

The general approach used to develop each of the power allowances was to identify the quantity and design parameters of illumination that are needed for each application, based on recommendations of IESNA. The selected design criteria vary with each of the lighting zones corresponding to the IESNA recommendations for different outdoor lighting ambient conditions. LZ1 needs the least light and LZ4 needs the most. Appropriate lighting equipment was determined for each application. Readily available, commonly used, moderately efficacious lighting sources were used for these models. This is a substantial conservatism in the analysis because higher efficacy sources than those that were used for these models are available and cost effective.

Lighting models were developed that represent each lighting application. The models include assumptions about the geometric characteristics of the lighting application and other parameters that are relevant in determining a reasonable Lighting Power Density (LPD), including luminaire photometrics, mounting heights, spacing, and the average, maximum, minimum, and maximum to minimum footcandle levels. In some cases, the spacing of the luminaries and other features change for each lighting zone. Calculations were performed for each of the models using the selected lighting equipment. The lighting equipment and lighting layout were modified until the design criteria were satisfied. The lighting power used to meet the criteria is the basis of the proposed standards.

These requirements are applicable to:

- Unconditioned Buildings
- Hardscape for automotive vehicular use, including parking lots, driveways and site roads
- Hardscape for pedestrian use, including plazas, sidewalks, walkways and bikeways
- Building entrances and facades
- Canopies for vehicle service stations, other sales canopies, and non-sales canopies
- Outdoor sales lots
- Ornamental lighting

These requirements are not applicable to:

- Temporary outdoor lighting
- Lighting required and regulated by the Federal Aviation Administration, and the Coast Guard
- Lighting for public streets, roadways, highways, and traffic signage lighting, including lighting for driveway entrances occurring in the public right-of-way
- Lighting for sports and athletic fields
- Lighting for industrial sites, including but not limited to, rail yards, shipyards and docks, chemical and petroleum processing plants, and aviation facilities
- Automated Teller Machine lighting
- Lighting of public monuments
- Lighting used in or around swimming pools, water features, or other locations subject to Article 680 of the California Electrical Code
- Lighting of tunnels, bridges, stairs, and ramps
- Landscape lighting

A 2002 baseline survey[7] of current outdoor lighting practice in California suggests that many existing outdoor lighting systems already use no more than the allowed power budgets established by these standards.

Initial costs will be equal to or less than current practice. Energy operating costs will be lower so the proposed measures will result in lighting designs that are cost effective

- See Appendix A for lighting model information

Signs

For signs a different approach has been taken, based on manufacturers' recommendations. The sign energy standards apply to all internally and externally illuminated signs, for both interior and exterior applications. Lighting Zones do not apply to signs. Two compliance options are offered that allow the use of available cost effective lighting technologies. The first option is a lighting power allowance for internally illuminated and for externally illuminated signs. The second option is the allowed use of specific energy-efficient lighting technologies, including electronic ballasts, pulse-start or ceramic metal halide, high pressure sodium, neon, cold cathode, light emitting diodes, barrier coat rare earth phosphor fluorescent lamps, or compact fluorescent lamps that do not contain medium based sockets. This approach provides wide flexibility for compliance, a simple prescriptive approach for using energy efficient technologies and a performance approach allowing the market to introduce, develop and use promising new lighting technologies that meet the power allowances.

These requirements are not applicable to:

- Traffic Signage Lighting
- Exit signs (Exit signs must meet the requirements of the Appliance Efficiency Regulations)

Most of the allowable alternate lighting technologies are already used in signage. However, this standard will have the greatest impact on those signs that currently use either fluorescent high-output lamps with magnetic ballasts, probe-start metal halide systems, or incandescent lamps. The following tables show that electronic ballasts as a replacement for magnetic ballasts for high output fluorescent lighting systems, pulse-start metal halide as a replacement for probe-start metal halide lighting systems, and compact fluorescent as an alternative for incandescent lighting systems are cost effective.

Table 2

Magnetic ballast compared to electronic ballast for T12 HO fluorescent systems in internally illuminated signs

Assumptions		
Sign Width	11 feet	
Sign Height	8 feet	
Total Square feet	88	
Number of lamps used at 12” on center	10	
Hours of operation per day	10	
Days of operation per year	365	
	Magnetic Ballast	**Electronic Ballast**
Lineal feet of lamp per ballast	20	20
Input watts per ballast	304	198
Number of ballast needed	4	4
Total system watts	1,216	792
Watts per square foot	13.8	9.0
Cost per ballast	$ 40	$ 60
Energy Reduction per sign per year	1,548 kWh	
Total extra costs per sign	$ 80.00	
Net present value per kWh, assuming a 15 year life	$1.37/kWh	
Net present value of the savings	$2,121	

Table 3

Probe-start metal halide compared to pulse-start metal halide lighting system for internally illuminated signs

Assumptions		
Sign Width	30 feet	
Sign Height	10 feet	
Total Square feet	300	
Number of lamps	24	
Hours of operation per day	10	
Days of operation per year	365	
	Probe Start	**Pulse Start**
Watts per lamp	250	175
System input watts per lamp plus ballast	295	208
Number of ballasts per sign	24	24
Total watts per sign	7,080	4,992
Watts per square foot	23.6	16.64
Mean lamp lumens	13,500	12,500
Average lamp life (hours)	10,000	15,000
Point in life where mean lumen occurs at 40% of rated life (hours)	4,000	6,000
Cost per lamp	$23	$ 32
Number of lamps per ballast in 15 years	6	4
Cost per ballast	$27	$ 47
15 year cost for lamps + ballast	$3,960	$4,200
Energy Reduction per sign per year	7,621 kWh	
Total extra costs per sign	$ 240	
Net present value per kWh, assuming a 15 year life	$1.37/kWh	
Net present value of the savings	$10,441	

Table 4

Probe-start metal halide compared to pulse-start metal halide lighting system for billboards

Assumptions		
Sign Width (ft)	48	
Sign Height (ft)	14	
Total Square feet	672	
Number of luminaires per sign	4	
Hours of operation per day	10	
Days of operation per year	365	
	Probe Start	**Pulse Start**
Watts per lamp	400	320
System input watts per lamp per ballast	450	355
Number of ballasts per sign	4	4
Total watts per sign	1,800	1,420
Watts per square foot	2.7	2.11
Mean lamp lumens	23,400	23,800
Average lamp life (hours)	20,000	20,000
Cost per lamp	$24.24	$31.11
Number of lamps per ballast in 15 years	3	3
Cost per ballast	$53.36	$57.58
15 year cost for lamps + ballasts	$504.32	$603.64
Energy Reduction per sign per year (kWh)	1,387	
Total extra costs per sign	$99.32	
Net present value per kWh, assuming a 15 year life	$1.37/kWh	
Net present value of the savings	$1,900	

Table 5

Halogen Parabolic Aluminized Reflector (PAR) incandescent compared to compact fluorescent for externally illuminated signs

Assumptions		
Sign Width (ft)	8	
Sign Height (ft)	3	
Total Square feet	24	
Number of luminaires per sign	2	
Hours of operation per day	10	
Days of operation per year	365	
	Halogen PAR Incandescent	**Compact Fluorescent**
Watts per luminaire	90	28.6
Total watts per sign	180	57.20
Watts per square foot	7.8	2.48
Average lamp life (hours) [1]	6,000	10,000
Cost per lamp	$3.99	$2.99
Number of lamps per luminaire	1	2
Number of lamps per sign in 15 years	18.25	21.9
15 year lamp costs	$72.82	$65.48
Luminaire costs (ea)	$6.90	$26.96
15 year luminaire + lamps costs	$86.62	$119.41
Energy Reduction per sign per year (kWh)	448	
Total extra costs per sign	$32.79	
Net present value per kWh, assuming a 15 year life	$1.37/kWh	
Net present value of the savings	$614.	

[1] Many Halogen PAR lamps have less than 6,000 hour rated life. In those cases, the cost of the incandescent system will be more than the cost of the compact fluorescent system.

Unconditioned Buildings

For nonresidential and high-rise residential buildings and hotels/motels, existing building energy efficiency standards limited the lighting power that can be installed in interior spaces, but the limits only applied to spaces that were conditioned or semi-conditioned as defined by the standards. The current standards do not apply to unconditioned warehouses, unconditioned manufacturing facilities, or other unconditioned spaces. The proposed interior lighting standards apply to both conditioned and unconditioned spaces.

The scope of the Title 24 building energy efficiency standards has been expanded to include requirements for unconditioned spaces. The requirements include prescriptive lighting power density requirements and mandatory lighting control requirements. Adding unconditioned buildings to the standards utilizes measures that are already identified for the 2005 standards revision or already included in Title 24 for conditioned buildings. While the parking garage model and standard are new, the others are not. The lighting technologies used as the basis of all of these measures are the same.

The existing models of conditioned buildings work well for unconditioned buildings, since the tasks are the same. No California Energy Commission model existed for parking garages, so a new one has been developed.

The technologies and equipment that are expected to be used to meet the requirements for unconditioned buildings are the same as those for conditioned buildings, and the cost effectiveness is the same as has been demonstrated in past Standards updates. Cost effectiveness of lighting technologies that may be used to meet the lighting power densities is documented in "Measure Analysis and Life-Cycle Cost, Part I," pp. 5-7 at: http://www.energy.ca.gov/2005_standards/documents/2002-04-23_workshop/2002-04-23_WORKSHOP_REPORT.PDF .

Appendix A
Lighting Models

Note to Readers: This Staff Report was initially published prior to the adoption of the 2005 Building Energy Standards. Other than the clarifications in this note, the rest of this report is identical to the July 2003 Staff Report. Information about specific luminaries was provided in the July 2003 Staff Report so that readers had all of the information necessary to replicate, and validate that the lighting models would meet the proposed outdoor lighting power allowances. The products that were listed in the summaries of the models in Appendix A are simply representative of commonly available, average performing equipment, not an endorsement of those products.

Since the publication of the original version of this Staff Report in July 2003, the Energy Commission was contacted by Visionaire Lighting stating that they also manufacture luminaires that perform just as well as the luminaires listed in Appendix A. The Energy Commission agrees that the performance of the Visionaire products is similar to the products used in our modeling. The Energy Commission does not endorse specific manufacturers or products. There are many different luminaires, manufactured by many different companies that can be used to meet the lighting power allowances given proper lighting design.

This appendix contains lighting model [8] information used to support the 2005 Title 24 Outdoor Lighting Standards. Lighting modeling has occurred throughout the process of developing the Outdoor Lighting Standards.

Models were created in Lumen Micro 2000 using photometric data from Lithonia Lighting, LSI Industries and Se'lux. The type of luminaire and layout are shown in the following tables describing each model.

Photometrics

Photometric files directly from the manufacturers' web sites were used.

- Lithonia "Boulevard" full cutoff luminaires for most parking lot studies. This is a family of good performing shoebox style luminaires from North America's largest manufacturer of lighting equipment.
- Lithonia "KKR" full cutoff luminaires for some parking lots and circulation areas of other lots. The KKR is a family of competitively priced luminaires with offerings in low wattages and a variety of distributions.
- LSI Industries "Greenbrier" full cutoff area and auto display luminaires. LSI is a major manufacturer with significant market penetration in the auto dealer and petroleum sales markets. The Greenbrier family is a competitive product family.
- Lithonia Lighting G series recessed HID downlights for gas station canopies. We cross checked them against LSI Richmond flat lens luminaires and found comparable results from both (see below).
- Lithonia "Advantage" series HID and compact fluorescent downlights for other canopies.

Models Generated

In general, the models were large areas for which we studied a part of the area for light level and uniformity. Raw Lumen Micro files are available for some of the models to illustrate the method of analysis.

Table A-1

Parking Lot Studies

Study	Topic	Lighting System	Performance	Power Density
Parking Lot Study 1	Parking Lot/hardscape	Lithonia Boulevard Type III 250 w 35’ every other row	1.7 fc average @ <12:1 max/min Target: 1.5	0.05 w/sf Target: 0.08 w/sf Lighting Zone 2
Parking Lot Study 2	Parking Lot/hardscape	Lithonia Boulevard Type III 400 w 35’ every other row	3.1 fc average @ <12:1 max/min Target: 3.0	0.07 w/sf Target: 0.19 w/sf Lighting Zone 4
Parking Lot Study 3	Parking Lot/hardscape	Lithonia Boulevard Type III 175 w 35’ every other row	0.99 fc average @ <16:1 max/min Target: 1.0 average	0.03 w/sf Target: 0.05 w/sf Lighting Zone 1
Parking Lot Study 4	Parking Lot/hardscape	Lithonia Boulevard Type III 175 w 20’ every row	2.99 fc average @ <12:1 max/min Target: 3.0 average	0.09 w/sf Target: .19 w/sf Lighting Zone 4
Parking Lot Study 5	Parking Lot/hardscape	Lithonia Boulevard Type III 100 w 20’ every row	2.97 fc average @ <8:1 max/min Target: 3.0 average	0.09 w/sf Target: .19 w/sf Lighting Zone 4
Parking Lot Study 6	Parking Lot/hardscape	Lithonia Boulevard Type III 175 w 20’ every row	2.00 fc average @ <8:1 max/min Target: 1.5 fc average	0.05 w/sf Target: 0.08 w/sf Lighting Zone 2
Parking Lot Study 7	Parking Lot/hardscape	Lithonia KKR Type V 70 w 20’ in lot center on 70 x 80 centers and Type III 70 watt along edges 80’ OC	0.61 fc average@ <8:1 max/min Target: 0.5 fc average	0.02 w/sf Target: 0.05 w/sf Lighting Zone 1
Parking Lot Study 7A	Parking Lot/hardscape	Selux Type V 100w 20’ in lot center on 70 x 80 centers and Lithonia KKR Type III 70 watt along edges 80’ OC	0.54 fc average @ <6:1 max/min Target: 0.5 fc average	0.03 w/sf Target 0.05 w/sf Lighting Zone 1

Table A-2

Outdoor Sales Frontage Studies

Study	**Topic**	**Lighting System**	**Performance**	**Power Density**
Front Row Study 1	Vehicle sales	LSI Greenbrier Flat Lens 1000w MH – front row photometry – 25 foot poles 40 feet on centers, 2 luminaires each	76 fc average @ <10:1 max/min over front row of cars (0-20' from edge of lot) Target 75 fc	52.8 w/lf Target 55 w/lf Lighting Zone 4
Front Row Study 2	Vehicle sales	LSI Greenbrier Flat Lens 1000w MH – front row photometry – 25 foot poles 31 feet on centers, 1 luminaires each	52.6 fc average @ <10:1 max/min over front row of cars (0-20' from edge of lot) Target 50 fc	35.2 w/lf Target 38.5 w/lf Lighting Zone 3
Front Row Study 3	Vehicle sales	LSI Greenbrier Flat Lens 1000w front row photometry – 20 foot poles 50' on centers, 1 luminaire each	26.2 fc average <10:1 max/min over front row of cars (0-20" from edge of lot) Target 25 fc	22.0 w/lf Target: 22.5 w/lf Lighting Zone 2

Table A-3

Outdoor Sales Lot Studies

Study	Topic	Lighting System	Performance	Power Density
Sales Lot Study 1	Vehicle sales and outdoor sales	LSI Greenbrier Flat Lens Standard throw – 4 1000 watt luminaires on 30 foot poles spaced 55x80	52.7 fc average <2:1 max/min throughout the center 50% of the lot Target 50 fc	1.0 w/sf Target: 2.0 w/sf Lighting Zone 4
Sales Lot Study 2	Vehicle sales and outdoor sales	LSI Greenbrier Flat Lens Standard throw – 2 1000 watt luminaires on 30 foot poles spaced 55x80	26.2 fc average <2:1 max/min throughout the center 50% of the lot Target 25 fc	0.5 w/sf Target: 1.25 w/sf Lighting Zone 3
Sales Lot Study 2A	Vehicle sales and outdoor sales	LSI Greenbrier Flat Lens Standard throw – 4 1000 watt luminaires on 30 foot poles spaced 110x80	25.9 fc average <3:1 max/min throughout the center 50% of the lot Target 25 fc	0.5 w/sf Target: 1.25 w/sf Lighting Zone 3
Sales Lot Study 3	Vehicle sales and outdoor sales	LSI Greenbrier Flat Lens Standard throw – 2 1000 watt luminaires on 30 foot poles spaced 110x80	12.9 fc average <3:1 max/min throughout the center 50% of the lot Target 10 fc	0.25 w/sf Target: 0.70 w/sf Lighting Zone 2

Table A-4

Canopy Studies

Study	Topic	Lighting System	Performance	Power Density
Canopy Study 1	Gas Stations and Retail Canopies	Lithonia G1-250T73 250w MH –12 fixtures	28 fc @ <5:1 max/min in outer quadrant; 35.6 fc @ <4:1 max/min in center half Target 25 fc	1.22 w/sf Target 1.25 w/sf Lighting Zone 3
Canopy Study 2	Gas Stations and Retail Canopies	Lithonia G3-400T73 400w MH –12 fixtures	59.2 fc @ <5:1 max/min in outer quadrant; 72 fc @ <4:1 max/min in center half Target 50 fc	1.91 w/sf Target 2.00w/sf Lighting Zone 4
Canopy Study 3	Gas Stations and Retail Canopies	Lithonia 6" lensed 100w MH–16 fixtures	11.3 fc @ <6:1 max/min in outer quadrant; 13.4 fc @ <4:1 max/min in center half Target 10 fc	0.67 w/sf Target 0.70 w/sf Lighting Zone 1
Canopy Study 4	Gas Stations and Retail Canopies	Lithonia 6" lensed 100w MH– 24 Fixtures	13.6 fc @ <4.6 max/min in outer quadrant; 16.8 fc @ <2.9 max/min in center half Target 15 fc	0.933 w/sf Target 1.00 w/sf Lighting Zone 2
Canopy Study 5	Non-Sales Canopies	Lithonia 5" single PL-13 recessed	1.0 fc @ < 4:1 in center 50%. Target 1.0 fc	0.10 w/sf Target 0.12 w/sf Lighting Zone 1
Canopy Study 6	Non-Sales Canopies	Lithonia 6" recessed 2-PL13	2.0 fc + <5:1 everywhere Target 2.0 fc	0.24 w/sf Target 0.25 w/sf Lighting Zone 2
Canopy study 7	Non-Sales Canopies	Lithonia 6" lensed 100 watt MH fixtures	6.98 fc @ <5:1 max/min in outer quadrant; 7.32fc @ <4:1 max/min in center half Target 5 fc	0.38 w/sf Target 0.50 w/sf Lighting Zone 3
Canopy study 8	Sales Canopies	Lithonia 6" lensed 100 watt MH fixtures	14.1 fc @ <5:1 max/min in outer quadrant; 17.4 fc @ <4:1 max/min in center half Target 15 fc	0.84 w/sf Target 1.00 w/sf Lighting Zone 3

Table A-5

Site Road Studies

Zone	LPD Actual/ target 2 lane	LPD Actual/ target 4 lane	Horizontal Illumination FC Avg and Min 2 lane	Horizontal Illuminatio n FC Max/Min	Horizontal Illumination FC Avg and Min 4 lane	Horizontal Illumination FC Max/Min
LZ1	.018/.04	.023/.04	.54/.16	6.80	.77/. 35	3.39
LZ2	.030/.06	.039/.08	1.02/.36	4.51	1.51/. 75	3.08
LZ3	.047/.08	.053/.08	1.23/.44	4.51	.1.78/. 97	3.21
LZ4	.082/.15	.070/.15	1.98/1.43	1.84	2.2/1.43	2.16

Table A-6

Walkway Studies

Model/z one	LPD Actual/ Target	Lighting Power per unit length	Horizontal Illumination FC Avg	Horizontal Illumination FC Max/Min	Vertical FC Along Avg.	Vertical FC Across Avg.
LZ1	.05/.05	1.0/1.0	0.72	15.8	0.53	0.08
LZ2	.08/.08	1.5/1.5	1.09	4.84	0.87	0.57
LZ3	.10/.11	2.0/2.5	1.27	4.25	1.05	1.05
LZ4	.20/.21	4.1/5.0	1.94	3.54	1.73	1.35

Table A-7

Building Entrance Studies

Model /zone	LPD Actual/ Target	Horizontal Illumination FC Avg	Horizontal Illumination FC Max	Horizontal Illumination FC Min	Horizontal Illumination FC Max/Min
LZ1	.26/.35	1.72	3.91	0.24	16.0
LZ2	.43/.5	2.79	6.38	0.35	19.8
LZ3	.63/.7	4.55	5.79	2.63	2.2
LZ4	.85/1.0	6.06	7.72	3.51	2.2

Table A-8

Building Façade Studies[9]

Model/ Zone	Lamp Type	Façade Illuminance (FC)	Façade Dimensions (ft wide x ft tall)	Required Flux (Lumens)	Minimum Computed Power (Watts)	Allowed Lighting Power Density
LZ2	Compact Fluorescent	3	75 x 9	2025	122	0.18
	28 W T-5	3	75 x 12	2700	143	0.18
LZ 3	28 W T-5	5	75 x 12	4500	179	0.35
	Metal Halide	5	75 x 12	4500	268	0.35
	Metal Halide	5	150 x 35	26250	1563	0.35
LZ 4	Metal Halide	10	75 x 12	9000	451	0.50
	Metal Halide	10	150 x 48	72000	3189	0.50

Table A-9

Use it or Lose it Ornamental Lighting Allowance

Model/ Zone	Site Net square feet	Allowed Watts per square foot	Allowed Ornamental Watts per site	Number Ornamental Luminaires Allowed if wattage used is:		
				100 Watts	50 Watts	25 Watts
LZ2	40,000	0.01	400	4	8	16
	200,000		2,000	20	40	80
LZ 3	40,000	0.02	800	8	16	32
	200,000		4,000	40	80	160
	400,000		8,000	80	160	320
LZ 4	40,000	0.04	1,600	16	32	64
	200,000		8,000	80	160	320
	400,000		16,000	160	320	640

[1] New Buildings Institute. "Outdoor Lighting Baseline Assessment, Integrated Energy Systems Productivity and Building Science." November 11, 2002

[2] Commission Internationale de l'eclairage. "Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations"

[3] Illuminating Engineering Society of North America. RP-33-99 "Lighting for Exterior Environments." New York, NY: IESNA. 1999

[4] NEMA "White Paper on Outdoor Lighting Code Issues," August 1, 2000

[5] NEMA "Statement of Principles on Outdoor Lighting Codes of the National Electrical Manufacturers Association," rev. April 27, 2001

[6] Phone conversation between Dr. Alan J. Lewis, O.D., Ph.D., England College of Optometry, Boston, MA, and Gary Flamm, California Energy Commission, June 24, 2003

[7] New Buildings Institute. "Outdoor Lighting Baseline Assessment, Integrated Energy Systems Productivity and Building Science." November 11, 2002

[8] Note: these lighting models were generated for this project by James R. Benya, PE, FIES, IALD, LC; Benya Lighting Design

[9] Information in this table was obtained from Table 24 in the "Outdoor Lighting Research, California Outdoor Lighting Standards," California Energy Commission, June 6, 2002